Answers to Problems

In the following answers, the rules for Significant Figures will be applied. Answers will be given to correspond to the smallest number of significant figures in the numerical information and applied after the computation is completed. Example: (1.346 x 1.23) x 3.45 = 5.711751 but with SF applied to 3 SF you get the final answer of 5.71.

11 - Exploring the Atmosphere of Pluto - How does the scale height of Pluto's atmosphere change as it orbits the sun if the average atmosphere molecule mass (N_2) is 4.7×10^{-26} kg, and g for Pluto is 0.66 m/sec^2. **ANSWER:** At closest: T = 55 k so H = $(1.38 \times 10^{-23})(55)/(4.7 \times 10^{-26})(0.66)$ = 24 kilometers. At farthest: T = 33k so H = 24.5 x (33/55) = 15 kilometers.

12 - Mysteries of the Kuiper Belt - If the Kuiper Belt is a disk with radii of 39 AU and 48 AU, with a thickness of 10 million km, what is the average distance between KBOs if there are one billion of them in this volume of space? (Hint: 1 AU = 150 million km). **ANSWER:** Volume = $\pi(48^2 - 39^2)$(10 million/150 million) = π(2304 - 1521)(0.066AU) = 160 cubic AUs. Density of particles = 1 billion/160 = 6.2×10^6 KBOs per cubic AU. The average distance is then $1/(6.2 \times 106)^{1/3}$ = 0.0055 AUs. This is a distance of about 820,000 km, or about 3 times the Earth-Moon distance.

13 - The Journey Beyond Pluto: What's Next? - Search the Internet for images of the smaller moons of Jupiter, Saturn, Uranus and Neptune. Create a sketch of what you think 2014 MT69 or 2014 MT70 might look like, close-up. Describe why you selected the shape and features that you used. **ANSWER:** These objects are about 60 km across and are in the outer solar system where icy objects are common. For example, the moon of Saturn called Prometheus is about this size and there is a clear image of it taken by Cassini. It is potato-shaped and lightly cratered.

14 - The Solar System from Pluto: Looking Back - Draw a scaled diagram of what each of the planets would look like as they pass across the face of the sun as viewed from Pluto. Will the planets appear as colored disks with surface details, or as black disks? Explain. **ANSWER:** They will appear as black disks because they will be located exactly between the sun and Pluto when they cross and so will not appear illuminated by the sun. If you draw a circle 10 cm in diameter representing the sun (38 asec in diameter), the diameters of each of the planets to this scale will be Earth (0.3 asec)= 0.8 mm, Mars (0.2 asec) = 0.5 mm, Jupiter (4.3 asec) = 11 mm, Saturn (3.9 asec) = 10 mm ,Uranus (6.3 asec) = 17 mm, Neptune (3.7 asec) = 10 mm.

15 - Solar Eclipses from Pluto? - Create a sketch from the surface of Pluto to show what the solar eclipses created by Nix and Hydra would look like. Nix's angular diameter is about 9 minutes of arc and Hydra's is about 7 minutes. Sun=1 arcminute. **ANSWER:** Draw a circle 1 cm in diameter to represent the sun. On this scale, Nix will be a circle 9 cm in diameter and Hydra will be 7 cm in diameter.

16 - Pluto: The twilight world. - The distance from Earth to the sun is 150 million km. From the closest and farthest distances to Pluto from the sun, by what factors is sunlight dimmer on the surface of Pluto during each of these times? If the solar panel on your roof measures 10 meter^2 to generate 2000 watts and costs $6000, how big would the same system be near Pluto to generate the same amount of power? **ANSWER:** Pluto's distance changes from 7.3 billion kilometers to 4.4 billion kilometers. Closest: (150 million/4.4 billion)^2 = 1/860 farthest (150 million/7.3 billion)^2 = 1/2400. A solar panel system at closest distance would have to have an area 860x10 m^2 = 8600 m^2 and cost 860x$6000 = $5.16 million. At the farthest distance it would cover an area of 24000 m^2 and cost $14.2 million.

17 - The New Horizons Spacecraft: Close-up - From the dimensions and clues given in the two drawings, what is the volume in cubic meters of the triangular spacecraft body, not including the portion labeled

'spacer' or the RTG unit? (Hint: Consider the spacecraft as a collection of squares, rectangles, triangles and their individual 3-D volumes). **ANSWER:** The spacecraft looks like an equilateral triangle with a rectangle attached to its base, and the tip of the triangle cut off. From the top view, the rectangular base measures 82 inches (208 cm) long and by using the drawing scale its width is about 24 inches (61 cm) and from the side view it has a depth of 27 inches (68.6 cm) for a volume of 208cm x 61cm x 68.6 cm = 870,000 cm3. The triangular piece with part of its tip cut off near the RTG is a bit trickier to estimate. It is an equilateral triangle with a side length of 82 inches (208 cm). The area of an equilateral triangle is

$s^2 \frac{\sqrt{3}}{4}$ where s = 208 cm, so A = 18,700 cm^2, but the tip of this triangle has been removed. This tip is another smaller equilateral triangle with a side length from the drawing that is about 59 cm, so its areas is 1,500 cm^2. So the clipped triangular face of the spacecraft has an area of 18,700 - 1,500 = 17,200 cm^2. The width of the spacecraft is 68.6 cm, so the volume is 1,180,000 cm^3. When this is added to the volumes of the base rectangle we get 2,050,000 cm^3. Since one cubic meter is 1 million cm^3, the volume of the spacecraft is about 2.1 cubic meters.

18 - The Transmission of Images from Pluto. - From the distance of Pluto, the New Horizon spacecraft can transmit data at a rate of 1,000 bits per second. Each image contains 1024x1024 pixels, and each pixel is coded with 12-bits of intensity data. How long will it take to transmit to Earth one of these uncompressed images? How long will it take if the image is compressed to 2.5 megabits before sending? **ANSWER:** Total pixels = 1024x1024 = 1,049,000. Total bits = 12 x 1,1049,000 = 12,600,000. At 1,000 bits/sec it will take 12,600 seconds or 3.5 hours. With compression to a 2,500,000 bit file, it will take 2,500 seconds or 42 minutes.

19 - Exploring Dwarf Planet Haumea - Astronomers sometimes use a single number to represent the diameter of an object that is not perfectly round. How many different diameter definitions can you come up with for Haumea? **ANSWER:** Average diameter: (1920+1540+990)/3 = 1,480 km. Radius based on volume of equivalent sphere. $4/3\pi R^3$ = 1920x1540x990=$2.93x10^9$ km^3 so R = 882 km, and diameter = 1,770 km.

20 - Exploring Dwarf Planet Makemake - From the measured diameter, what is the mass of Makemake if it consisted of water ice with a density of 917 kg/m^3 ? Suppose it consisted only of common granite rocks with a density of 2700 kg/m^3, what would its mass be? **ANSWER:** Radius = 1434/2 = 717 km. Volume = 4/3 (3.14)$(717000)^3$ = $1.54x10^{18}$ m^3. Density = $3x10^{21}$ $kg/1.54x10^{18}m^3$ = 2,000 kg/m^3. It probably contains about as much ice as a granite-like material.

21 - Exploring Dwarf Planet Eris - From the measured mass and diameter, what is the average density of Eris? If water ice has a density of 917 kg/m^3 and common granite rocks have a density of 2700 kg/m^3, what would be your best guess about the composition of Eris? **ANSWER:** Radius = 2326/2 = 1163 km. Volume = 4/3 (3.14)$(1163000)^3$ = $6.59x10^{18}$ m^3. Density = $1.7x10^{22}$ $kg/6.59x10^{18}$ m^3 = 2600 kg/m^3. It is probably mostly a granite-like material with very little ice.